OPTIMAL CV-22 CENTRALIZED INTERMEDIATE REPAIR FACILITY LOCATIONS AND PARTS REPAIR

GRADUATE RESEARCH PROJECT

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Abstract

The CV-22 Osprey is a revolutionary weapon system that is currently being fielded by Air Force Special Operations Command (AFSOC). It is a tilt-rotor aircraft that combines the speed of a conventional fixed wing turboprop aircraft with the flexibility of a helicopter. At the same time, the US Air Force logistics enterprise is turning more and more to centralized aircraft maintenance. The term for these centralized maintenance facilities is centralized intermediate repair facilities, or CIRF. The Headquarters AFSOC logistics directorate (A-4) is interested in determining where CIRF(s) for the CV-22 should be located and what parts should be repaired at a CIRF versus at the base where the aircraft is stationed. This research study analyzed cost and transportation time data to identify recommended CIRF locations. It also analyzed historical failure and demand data for particular CV-22 parts to determine which parts are candidates for CIRF repair and what stock levels should be established at the bases so that parts are available to repair the aircraft while the CIRF repairs failed parts.

Acknowledgements

I would like to thank my advisor, Dr. William Cunningham, for his support and guidance during this research. I would also like to acknowledge the many sacrifices my family made allowing me to complete this research project.

Ryan L. Rowe

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OPTIMAL CV-22 CENTRALIZED INTERMEDIATE REPAIR FACILITY LOCATIONS AND PARTS REPAIR

I. Introduction

1.1 Background

The CV-22 "Osprey" is a revolutionary new weapon system that is just now being fielded by Air Force Special Operations Command (AFSOC). It exploits "tilt-rotor" technology that allows it to fly like a standard turbo-prop fixed-wing airplane while also maintaining the flexibility inherent in vertical take-off and landing like a helicopter.

Because the CV-22 is still a relatively new weapon system, some of the logistics questions for the aircraft have not been answered. The AFSOC Directorate of Logistics (A-4) asked the author to research two areas: 1) Where should centralized intermediate repair facility(ies) (CIRFs) be established and 2) What parts and/or equipment peculiar to the CV-22 should be repaired at a CIRF.

While much more background on CIRFs can be read in the literature review, it would do well to define what a CIRF is here. A CIRF is an intermediate level of aircraft repair. Most continental US (CONUS) USAF bases today are designed upon a "three-level" maintenance concept. On-equipment maintenance is maintenance that is done directly to, or on, the aircraft. Off-equipment maintenance requires taking the part off the aircraft and is usually done using specialized equipment located in what is called "backshops", but still located at the main base. The final level is depot-level repair. In this case, the part or equipment must be sent to an aircraft or parts depot for repair. There are currently three main depots in the USAF: Tinker in Oklahoma City, OK, Ogden located at Hill AFB, UT, and Warner-Robins, located at Robins AFB, GA.

CIRFs are not a new concept, and have been experimented with since the inception of the USAF in 1947 (Gellar et al., 2004:4-5). In the CIRF concept, the "off-equipment" maintenance requirement for certain pre-identified parts and equipment is deleted at the main base, and instead, the parts or equipment are shipped to a centralized repair facility for repair. Keep in mind, however, that this is not depot level repair. The logistics involved is similar in that transportation costs, spares levels, and maintenance pipeline repair times all have to be considered. The main goal is to have a more efficient operation to repair parts. The secondary goal is to save money.

AFSOC has already begun implementing CIRF operations for several components. For example, all CONUS based AFSOC C-130 engines are CIRF repaired at Hurlburt Field, FL. Additionally, several avionics components from AFSOC aircraft are also CIRF repaired at Hurlburt Field, FL.

1.2 Problem Motivation

The realities of today's military, not just the USAF, demand that organizations find new and better ways of doing business. Budgets are shrinking, man-power is being reduced, and operations tempo is extremely high. One way the USAF aircraft maintenance community can relieve all three of the above is using CIRFs. The advantages of CIRFs are that you pool your manpower at one location. This achieves two things. One, it reduces the cost of man-power. For example, you may have three or more bases doing "backshop" maintenance with 80 people each. If you combine that operation at a CIRF, you will not need all 240 personnel (80 personnel X three bases). Instead, the efficiencies achieved by pooling your manpower will allow you to operate the CIRF with much less personnel, therefore reducing the personnel cost. Secondly,

with USAF-wide cuts in man-power, this allows you to achieve the same level of repair and readiness with fewer personnel by pooling your man-power at one location. Additionally, CIRFs tend to be "steady state", that is, they do not deploy forward. This allows the option of hiring civilian maintenance technicians (either government or contractor) to work in the CIRF, adding an even higher level of experience. Also, in the three-level maintenance concept, the backshops deploy forward with the aircraft taskings. By putting those backshop tasks at the CIRF, it reduces the operations tempo for those personnel, required fewer personnel to deploy, and to deploy less often.

1.3 Problem Statement

As stated before, the AFSOC A-4 has asked the author to look into CIRF options for the CV-22. In particular, they are interested in where CIRF operations should be established, and what parts and equipment from the CV-22 should be repaired at a CIRF. That being said, my research problem statement is: *Where should CV-22 CIRF operations be established and what parts and equipment should be repaired at a CIRF*.

1.4 Research Objectives

The research objective is to provide AFSOC A-4 well researched, feasible options for CV-22 CIRF operations. First, locations for CIRF operations will be analyzed using several criteria. Currently, plans call for basing the CV-22 at three CONUS bases, two of which are AFSOC bases. Cannon AFB, NM and Hurlburt Field, FL are both AFSOC bases. Kirtland AFB, NM is an AETC base, but it too has CV-22s and is the training base where all AFSOC CV-22 operators will train. The two main variables of interest for

this are costs to transport the parts requiring repair, and time required to transport the parts being repaired to and from the CIRFs.

Secondly, parts and equipment that are good candidates to be repaired will be identified. The author will use historical data on which parts and equipment have broken on the aircraft. The author will also analyze previous research performed on CIRF operations to assist in recommending which parts and equipment should be CIRF repaired.

1.5 Scope

The scope of this research project will focus only on AFSOC CV-22s. Research on CIRF locations will focus on locations that have, or will have, CV-22s based at them. Research on parts and equipment will focus only on CV-22 peculiar items, and items that meet the criteria described under the research objectives above.

1.6 Implications

This research can be used by decision makers at AFSOC A-4 to select a location for CIRF operations that is both economical and maximizes operations readiness. More importantly, this decision can be made early in the fielding of this new weapon system, precluding expensive reorganizations later.

1.7 Preview

This research paper is organized as follows. Chapter II reviews the relevant literature. Chapter III summarizes the methodology used in answering the research

problem. Chapter IV presents the findings and analysis of the research. Finally chapter V provides conclusions and makes recommendations for future research.

II. Literature Review

2.1 Introduction

Due to the scope of this research project, there are two main areas of interest that must be studied to fully grasp the context of this problem. First of all, one must understand the CV-22. The CV-22 is a revolution in aviation technology and is just now beginning to be fielded by AFSOC. In order to understand the complexity of this research problem, one must understand the complexity of this weapons system, its history, and its missions. Secondly, one must understand CIRF operations. The dynamics of operations, logistics, and command and control (C2) that is required to efficiently and effectively operate CIRFs must be researched. By understanding the complexity of both the aircraft and the CIRF repair operations, recommendations can be made for where and what parts should be repaired at a CIRF facility.

2.2 Development of the CV-22 "Osprey"

The CV-22 Osprey is a tilt-rotor aircraft capable of vertical or short take-off and landing. It combines the speed of a conventional turbo-prop aircraft with the flexibility of a helicopter. It is currently in use by the US Marines as the MV-22 and USAF as the CV-22.

The tilt-rotor concept is not new. Bell helicopter engineers first began to develop the concept in the early 1950's. They developed the XV-3, the first tilt-rotor research vehicle. The XV-3 first flew in 1955 and in December 1958, successfully converted from helicopter mode to airplane mode, showing that tilt-rotor capability was feasible. During the XV-3's testing cycle, the aircraft made 250 test flights and 110 conversions and

reconversions. Despite these successes, the aircraft suffered from multiple problems, mainly in the areas of flight controls, aircraft structure, and engines.

Figure 1: The XV-3 (US Air Force Photo)

As technology advanced, the concept was reexamined in the 1970's. The US Army and NASA contracted with Bell Helicopters to build a second tilt-rotor demonstrator. This aircraft was designated the SV-15. Two were built, and first flights were conducted in May 1978 with successful conversion to airplane mode occurring in July 1979. The program's success led to the development of the Joint Services Advanced Lift Aircraft (JVX) program designed to produce a medium-lift tilt-rotor aircraft for all four services (Currie, 1999:6-7).

In 1981, the US Army was named the executive agent for the JVX program. However, in 1983, the Army decided that they did not have a need for such an aircraft and backed out of the program. The US Navy was then named executive agent. It was then that the aircraft was given the designator "V-22". The V-22 first flew in 1989, but the then Secretary of Defense (SecDef), Dick Cheney, canceled the program arguing that tight budget constraints required funds to be prioritized elsewhere. Congress stepped in,

however, and in 1990 required the Department of Defense (DoD) to continue research and development. In 1991, Congress authorized funding for the USAF version of the V-22 (Settergren, 2000:8).

Unfortunately, the V-22 program has been plagued with multiple problems during its development history in the last 27 years. Safety of flight and maintenance concerns have hounded the program, including multiple accidents, three of which were fatal (Bolkom, 2006:4-5).

The V-22 program came under increased scrutiny in 2000 when an anonymous letter was mailed to the media claiming that the US Marine maintenance squadron commander had directed mechanics to falsify maintenance records to make the V-22's maintainability seem better than it was. The commander admitted this in January 2001 and was relieved of command. An independent investigation by the DoD Inspector General (IG) found that misconduct was committed by three Marines, two of which were reprimanded. In April 2001, a Blue Ribbon panel was convened by the SecDef to review the entire V-22 program. This panel recommended that the program continue despite concerns about the reliability and operational use of the aircraft, avoiding a possible termination of the program. In 2005, the V-22 program was finally approved by the DoD Acquisition Board for military use and full rate production (Bolkom, 2006:6-7, 10).

2.3 Technical Aspects of the CV-22

In order to understand the scope of this research project, it is important to understand the technical aspects of the CV-22. The CV-22 is a highly advanced aircraft, utilizing state-of-the-art technology in avionics, engines, and aircraft structures. The aircraft is powered by two Rolls Royce-Allison AE1107C turboshaft engines capable of

6,200 shaft-horsepower (shp) each. Additionally, the aircraft incorporates the latest in avionics technology. The aircraft is equipped with an AN/APQ-174 multi-mode radar that has terrain following/terrain avoidance (TF/TA) capability for low level flight. The aircraft also has the AN/ALQ-211 integrated radio-frequency (RF) countermeasure suite. For low light/low visibility operations, the aircraft is equipped with an AN/AAQ-16 forward looking infra-red (FLIR) system (Currie, 1999: 43-45).

Figure 2: The CV-22 Osprey (US Air Force Photo)

2.4 Centralized Intermediate Repair Facility (CIRF) History and Concept

The CIRF concept has been around for over 60 years. The USAF has at times embraced the centralized concept of aircraft maintenance (embodied by CIRFs), and at other times opted for decentralized maintenance, meaning a preponderance of maintenance actions take place at base-level. Centralized maintenance calls for multiple units and/or bases to utilize one or more intermediate maintenance facilities to support "off-equipment" maintenance, that is, repair of equipment/parts that must come off the

aircraft to be performed. The Rand Corporation, which has done multiple logistics studies for the USAF, refers to these as Forward Support Locations (FSL) (Gellar et al., 2004:4-5).

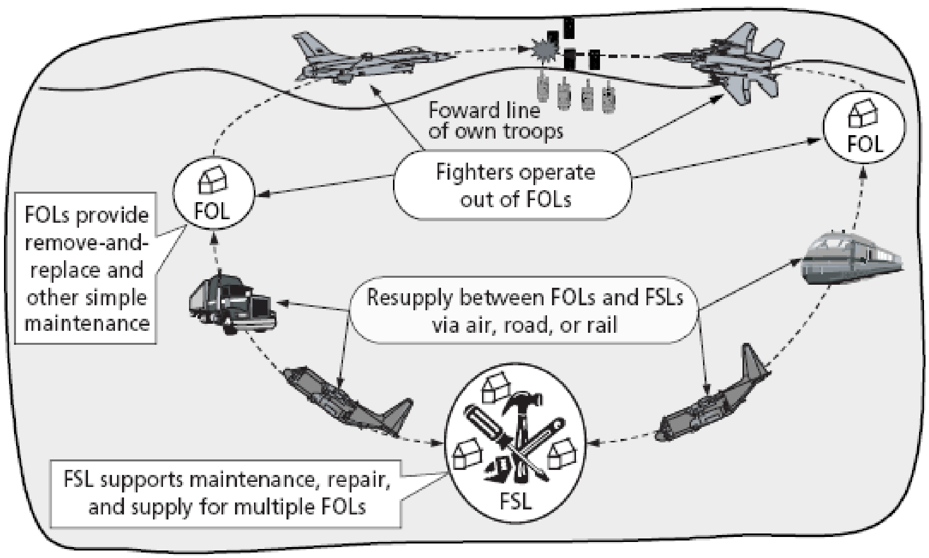


Figure 3: Illustration of the CIRF (FSL) Concept (Gellar et al., 2004:9)

Shortly after the USAF became an independent service in 1947, it found itself fighting its first war on the Korean peninsula. During the war, the USAF established what was called Reach-Echelon Maintenance Combined Operations (REMCOs) in Japan. These operations were essentially CIRFs, providing off equipment maintenance for aircraft operating in Korea. This concept proved very successful, with units supported by REMCOs having better mission capable rates, fewer aborts, flying more hours, and fewer accidents compared to units who continued to operate in the decentralized concept. However, the USAF in 1958 decided to opt again for decentralization, moving virtually all maintenance assets (people, parts, supplies, etc) under the base commander's authority (Gellar et al., 2004:18-19).

During the Vietnam conflict, the USAF again experimented with centralized maintenance. The USAF conducted a test code-named “Pacer Sort”. The Air Force used an F-4 fighter wing located at Cam Ranh Bay as a test bed. The test found centralized maintenance to have many benefits, including that both the centralized and decentralized test subjects fared well. However, other analyses concluded that the results were not clear enough to warrant centralized maintenance, and the Vice Chief of Staff of the USAF directed that maintenance would continue under the decentralized concept.

Experiments with CIRF operations continued throughout the 1970s, including studies done by US Air Forces Europe (USAFE), studies done by the Rand Corporation, and even by Strategic Air Command (SAC). However, none were conclusive enough to warrant full implementation of CIRF operations. In more recent times, CIRFs were stood up for Operations DESERT SHIELD/STORM and Operation NOBLE ANVIL (Serbia) (Gellar et al., 2004:21-30).

In fact, as recently as 1988, studies seemed to show that CIRFs were not as effective as decentralized maintenance in sustaining combat capability. In 1988, Hunt performed a research study on CIRFs’ impact on combat capability. In his study, Hunt found that CIRFs negatively impacted combat capability. Hunt stated “the sustained scenario results vividly depict the negative impact of centralization. Over time aircraft availability declines and reveals the relative advantage for organic JEIM” (1988:92). JEIM is Jet Engine Intermediate Maintenance.

As the USAF began to experience more and more expeditionary operations, while at the same time dealing with a large reduction in manpower during the restructuring of the 1990s, the USAF again looked to CIRFs as a manpower and deployment “footprint”

savings option. The USAF conducted another test in 2000 to see how CIRF operations would affect aircraft operations in Southwest Asia (SWA). Utilizing many recommendations from a previous Rand study, the USAF established a Regional Supply Squadron in USAFE to provide enhanced C2 to CIRF operations. During this study time frame, Operation ENDURING FREEDOM began as a result of the terrorist attacks of September 11, 2001. The results were clear, the CIRF concept had matured to a point where it could effectively support peacetime, and more importantly, major theater war, operations. A clear savings in manpower and equipment deployed coupled with effective support to units “down range” showed that the CIRF concept could work (Gellar et al., 2004:53-60).

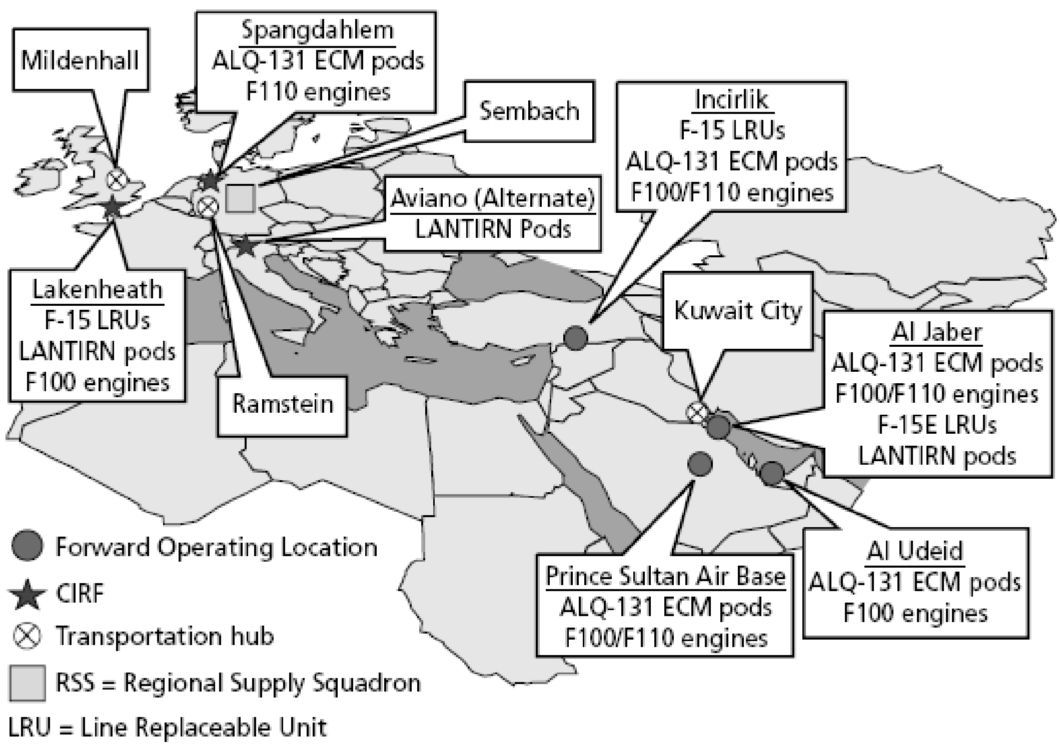


Figure 4: CIRF Test Operational Environment (Gellar et al., 2004:53)

2.5 CIRF Research Studies

The above information shows that CIRF operations are feasible, but should every part that comes off an aircraft be sent to a CIRF? A review of relevant literature shows that there are three major aircraft sub-systems that are candidates for CIRF. They are engines, some avionics, and pods (electronic warfare, targeting/navigation, etc.).

An interesting study was conducted on USAF Low Altitude Navigation and Targeting Infra-Red for Night (LANTIRN) pods. These are high demand assets used on F-16s and F-15Es that are a requirement for today's precision strike missions. At the time of the study, current policy was to decentralize the maintenance. Each unit had its own testers, tools, and equipment, and deployed with those assets. This test was conducted to see if acceptable levels of in-commission rates could be attained using CIRFs. As the authors noted, "the decision to centralize or decentralize...hinges not on the expected system cost but on the capability and risk levels the Air Force is willing to accommodate in its operations plans (Feinberg et al., 2000:6). The authors concluded that a networked system of FSLs and CONUS based support locations (CSLs) could support LANTIRN operations. However, the USAF must recognize that transportation is the chokepoint. If transportation is delayed, mission effectiveness degrades rapidly. The authors also warned that centralizing maintenance in one location also brings with it the inherent risk of enemy attack, and could be a single point of failure (Feinberg et al., 2000:7,40).

In that same vein, another study was conducted by Peltz et al. on repair options for F-15 avionics. Similar in the above study, this one was designed to test whether centralized maintenance had an effect on mission readiness of deployed F-15 avionics.

The impetus for this study was a serious decline in personnel retention in the F-15 avionics career field. The deployment burden had become such that people were "voting with their feet" and leaving the service. Additionally, avionics test equipment is very sensitive and requires a large amount of airlift to transport all the equipment to the forward operating location. Additionally, many units deployed with only one "string", or set of avionics equipment. That meant if that one set went down, the entire process was dead in the water. The authors of this study concluded that centralizing F-15 avionics maintenance for a major theater war would save 43 C-17 equivalents of cargo. In this study, the authors concluded that the optimal support solution would include four FSLs (AKA CIRFs) and one CSL (located at Seymour Johnson AFB, NC). However, like the LANTIRN pod study, the authors cautioned that transportation delays would seriously hamper the war effort. To offset this possibility, the authors recommend "a one time increase in spare parts for the supply pipeline" and cautioned "the risk may increase as customs regulations or the remoteness of the operating locations increase" (Peltz et al., 2000:xv-xix).

Amouzegar et al. in 2002 conducted a study for the USAF on centralizing maintenance on aircraft turbofan engines. This study is very interesting because aircraft engines are entirely different animals from avionics and pods. Most pods and avionics boxes are relatively small, with several assets able to be placed on a single 463L pallet. Engines are large, very sensitive components that require special handling, preparation, and require at least a whole pallet space on an aircraft (Amouzegar et al., 2002:7).

The researchers in this case used simulation modeling to conduct their test. Using maintenance data from USAF maintenance information systems (MIS), the researchers

ran simulation models for F-15 F100-229 and F100-220 engines, F-16 F100-220 engines, and the A-10 TF-34. Overall, the researchers found that CIRF operations had as good or better maintenance effectiveness that any of the other options tested. The other options the researchers tested against were the basic decentralized maintenance method while deployed (DecDep), home station operations, and CSL. For the A-10's TF-34 engine, the researchers found that because the good reliability of this engine, CSL operations could probably support this engine. A good illustration of the CIRF's effectiveness is the F100-229 simulation model. The F100-229 engine is one of the newest engines in the inventory used on F-15E aircraft. In this case, CIRF operations outperformed any of the other operations, as depicted in Figure 5. Decentralized-deployed operations did match CIRF operations, but only after 100 days in theater (Amouzegar et al., 2002:19, 34-35, 42).

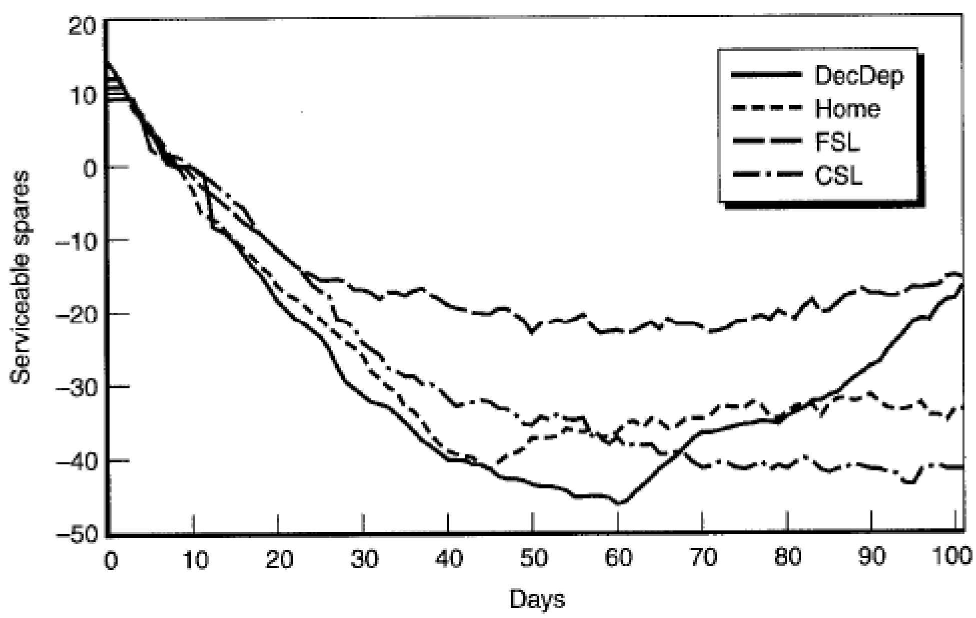


Figure 5: F100-229 Spares Performance for all Alternatives for the F-15 FOL
(Amouzegar et al., 2002:35)

A key theme keeps running through these studies. That theme is transportation. Without reliable, available, and prompt transportation, combat capability of deployed units suffers heavily. In 1997, Condon and Patterson conducted a study to compare organic military airlift cargo movement with that of commercial express carriers (in this case, Federal Express, better known as FedEx). The researchers concluded that FedEx did deliver cargo faster than military organic airlift, with a mean difference in the samples of approximately 3.5 days (Condon and Patterson, 1997:29). Transportation is the key factor in the success or failure of CIRF operations.

2.6 Summary

This review of relevant literature has covered the history, concept of operations, and technical aspects of the CV-22. Additionally, the history and concept of operations of CIRF operations was analyzed. By understanding these two focus areas, educated research can now be performed.

III. Methodology

3.1 Introduction

This chapter describes the research methodology for selecting CV-22 CIRF locations and what parts and equipment should be repaired at a CIRF. These are two separate research challenges to tackle. The first is where the CIRF should be located. The second is what parts and equipment from the CV-22 should be CIRF repaired.

3.2 Assumptions

There are several key assumptions in this study. The first assumption is that CV-22s will only be based at the three locations listed below:

1. Hurlburt Field, FL
2. Cannon AFB, NM
3. Kirtland AFB, NM

The second assumption is that transportation will be readily available. The third assumption is that the time it currently takes to repair a CV-22 part will stay constant, and will not vary when repaired at the CIRF. The fourth assumption is that the mean-time-between-failure will remain constant, and not degrade over time (repairing the same asset multiple times over X years). The next assumption is that the current maintenance data available for the CV-22 can be applied to the future fleet size and operational requirements. Another assumption is that the infrastructure necessary to do CIRF operations exists at each base. The final assumption is that transportation times and costs will remain constant, that is, shipping a part in May will take the same time and cost the same as shipping a part in September.

3.3 Methodology and Data Analysis for the Location of the CIRF

The optimal location of a CIRF is a balance of cost and transportation time. Transportation cost data and transportation time data obtained from commercial carrier websites were used to calculate these costs and times. Only commercial ground transportation was studied because all transportation will occur within the CONUS. In general, if there was a conflict between the cost and the speed of delivery, the speed of delivery was considered more important than the costs of delivery due to mission readiness issues. Transportation costs are secondary to mission readiness.

For this study, three different reparable types of equipment were used to determine optimal locations for the CIRF. First, the engine for the CV-22 was used. Secondly, a 150 pound avionics component was used to simulate larger avionics components. Lastly, a 50 pound avionics box was used to simulate smaller avionics components. Each item was simulated arriving at the CIRF in two different ways. The first way was simulating the item arriving from an overseas location to the CONUS at a port. The ports used for this study were Dover AFB, DE, and Travis AFB, CA. These two ports are the primary military ports of entry from the east coast and west coast, respectively. Secondly, each item was analyzed using shipping information between the potential CIRF locations (Kirtland AFB, NM, Hurlburt Field, FL, and Cannon AFB, NM). This would simulate the items moving from CONUS based locations to the CIRF. By doing this, it gave a complete cost picture of how much time and money it would cost to ship the items coming from overseas and between the CONUS bases.

The cost and time data was garnered from freightcenter.com. This website allows you to put in the exact criteria for the item you need to ship, including shipping class and

exact origin and destination. Once you inputted this information, it would give you quotes from 10 to 16 different shipping companies (depending on the item) for both cost and time. The costs for each company and the times for each company were averaged to provide a consistent, average cost in time and money to ship each item.

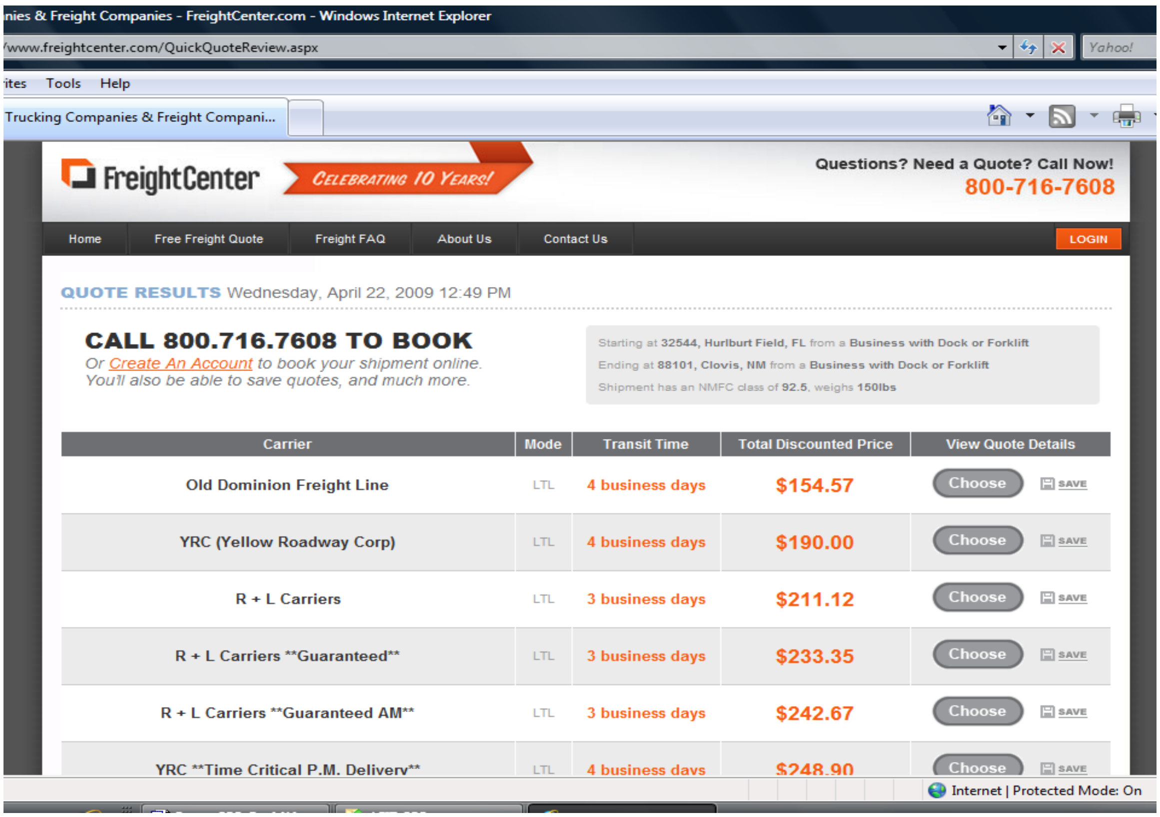
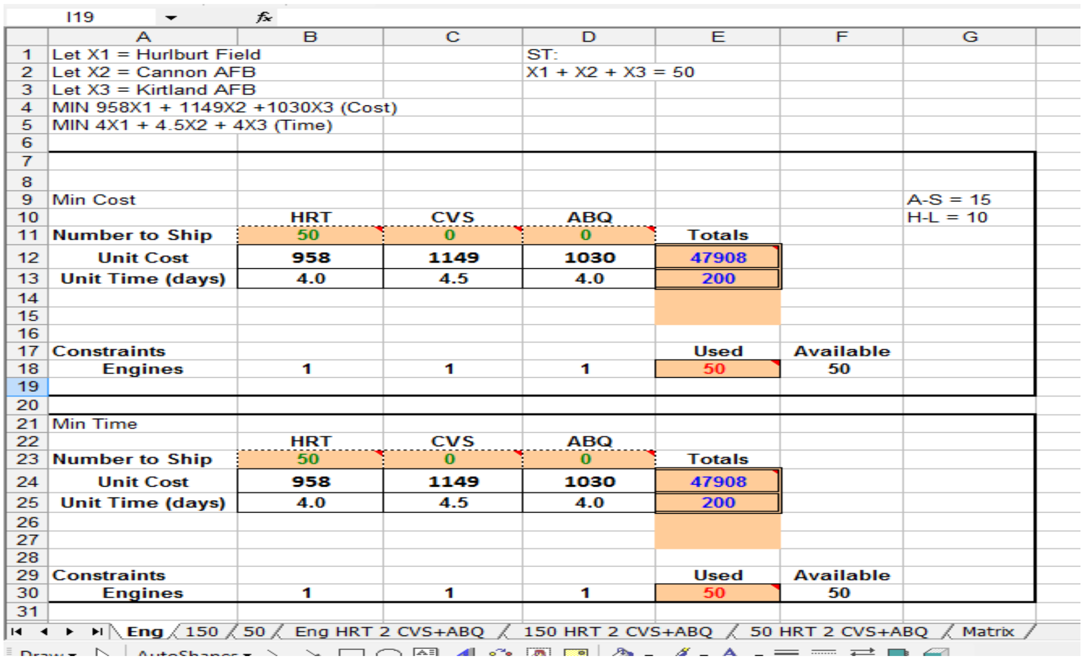


Figure 6: Results for Shipment Costs and Times from freightcenter.com

This averaged data was inputted into a linear programming model simulating two criteria. The first was the cheapest cost. The second was the fastest time. The figure below shows an example of the linear programming model used to simulate shipment of 50 engines from the ports to the three potential CIRFs. The number 50 was a random number used for simulation in the models.



	A	B	C	D	E	F	G
1	Let X1 = Hurlburt Field			ST:			
2	Let X2 = Cannon AFB			X1 + X2 + X3 = 50			
3	Let X3 = Kirtland AFB						
4	MIN 958X1 + 1149X2 +1030X3 (Cost)						
5	MIN 4X1 + 4.5X2 + 4X3 (Time)						
6							
7							
8							
9	Min Cost						A-S = 15
10		HRT	CVS	ABQ			H-L = 10
11	Number to Ship	50	0	0	Totals		
12	Unit Cost	958	1149	1030	47908		
13	Unit Time (days)	4.0	4.5	4.0	200		
14							
15							
16							
17	Constraints				Used	Available	
18	Engines	1	1	1	50	50	
19							
20							
21	Min Time						
22		HRT	CVS	ABQ			
23	Number to Ship	50	0	0	Totals		
24	Unit Cost	958	1149	1030	47908		
25	Unit Time (days)	4.0	4.5	4.0	200		
26							
27							
28							
29	Constraints				Used	Available	
30	Engines	1	1	1	50	50	
31							

Figure 7: Sample Linear Programming Model for Aircraft Engines

In this case, it is apparent that it was both cheaper and faster to ship the engines from the ports to Hurlburt Field, FL. These models were run for each of the three items simulating cost and time from both the ports and between the bases.

3.4 Methodology and Data Analysis for Parts and Equipment for CIRF Repair

The parts and equipment for CIRF repair were analyzed using several factors. First of all, previous studies regarding CIRF operations were studied for recommendations on which parts to be CIRF repaired. Secondly, historical data on part failures including numbers of failures and mean time between failures were analyzed to determine optimal spares allocation at the base level.

Based on the literature review, three items were considered for CIRF repair. These were aircraft engines, avionics components, and aircraft pods (targeting pods, electronic warfare pods, etc.). Based on this previous research, the information received

from HQ AFSOC regarding the number and types of aircraft parts failures was analyzed to determine which of these parts fell into the categories above (engines, avionics, pods).

From this research, 29 different components were identified as being potentially CIRF repairable. The historical break rate data for each of these parts was analyzed and forecasted demand was based on an average of the 18 months of data available. This data was then inputted into an Excel model along with data on order and ship time (OST) and service level rate to compute safety stock and reorder points for each item. Based on the results of these models, recommendations were made on stock levels for each part at the bases the CV-22 would be stationed.

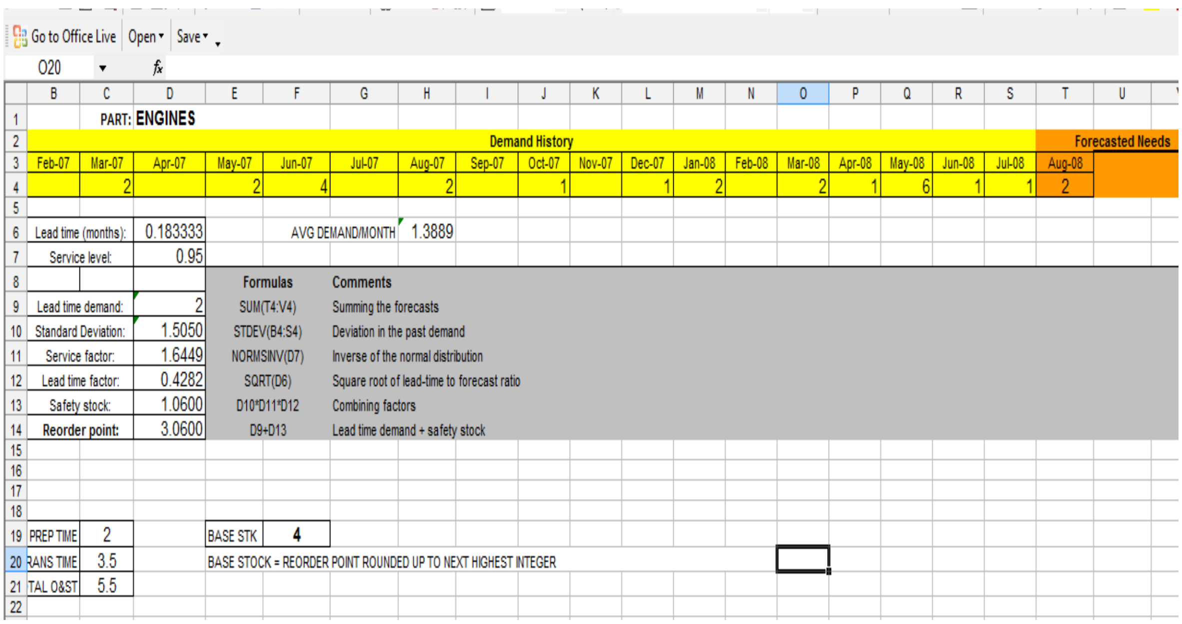


Figure 8: Excel Model for Safety Stock and Reorder Point for Engines

The service level rates for these models were set at .95. OST was derived from information provided by the 27th Special Operations Logistics Readiness Squadron at Cannon AFB, NM. If the average demand per month and reorder point information were fractions, they were rounded up to the next integer. For example, if the reorder point came out to be 3.06 engines, like in the figure above, it was rounded up to four engines.

3.5 Data Sources

Data sources for this study mainly came from two sources. The historical data for the parts and equipment, including number of times a part breaks and mean time between failure came from analysts at Headquarters AFSOC.

Data for transportation times and costs were derived from requesting price quotes from commercial carriers via the internet.

IV. Results and Analysis

4.1 Introduction

For this study, six linear program models were run to determine the optimal CIRF locations based on cost and transportation time. For engines, the model was run once to simulate engines coming from the ports, and a second time to simulate engines being transferred between the three bases of interest. For the 150 pound and 50 pound avionics components, the same scenarios were run.

Once the 29 aircraft parts to be studied were identified using the literature review of previous studies, the safety stock and reorder point Excel models were run for each one. This obviously totaled 29 different models.

4.2 Linear Program Models for Optimal CIRF location

The results of the linear program models for the aircraft engines showed that it was faster and less expensive to ship the engines to Hurlburt Field, FL from both the ports and between the bases. Each engine averaged $958 and 4 days to be shipped from the ports to Hurlburt Field and $1015 and 3.5 days to be shipped to/from Cannon AFB and Hurlburt Field. In the chart below, it should be noted that X1 is Hurlburt Field, X2 is Cannon AFB, NM, and X3 is Kirtland AFB, NM. HRT, CVS, and ABQ are the airport codes for each the bases, respectively. The number 50 is a random number used in the linear programming model to simulate the number of engines needing to be shipped.

	A	B	C	D	E	F	G
1	Let X1 = Hurlburt Field			ST:			
2	Let X2 = Cannon AFB			X1 + X2 + X3 = 50			
3	Let X3 = Kirtland AFB						
4	MIN 958X1 + 1149X2 +1030X3 (Cost)						
5	MIN 4X1 + 4.5X2 + 4X3 (Time)						
6							
7							
8							
9	Min Cost						A-S = 15
10		HRT	CVS	ABQ			H-L = 10
11	**Number to Ship**	50	0	0	**Totals**		
12	**Unit Cost**	**958**	**1149**	**1030**	47908		
13	**Unit Time (days)**	**4.0**	**4.5**	**4.0**	200		
14							
15							
16							
17	**Constraints**				**Used**	**Available**	
18	**Engines**	1	1	1	50	50	
19							
20							
21	Min Time						
22		HRT	CVS	ABQ			
23	**Number to Ship**	50	0	0	**Totals**		
24	**Unit Cost**	**958**	**1149**	**1030**	47908		
25	**Unit Time (days)**	**4.0**	**4.5**	**4.0**	200		
26							
27							
28							
29	**Constraints**				**Used**	**Available**	
30	**Engines**	1	1	1	50	50	
31							

Figure 9: Linear Programming results for Engines from the Ports

	A	B	C	D	E	F	G
1	Let X1 = Cannon AFB			ST:			
2	Let X2 = Kirtland AFB			X1 + X2 = 50			
3							
4	MIN 1015X1 + 1059X2 (Cost)						
5	MIN 3.5X1 + 3.7X2 (Time)						
6							
7							
8							
9	Min Cost						
10		CVS	ABQ	Variable cell			
11	**Number to Ship**	50	0				
12	**Unit Cost**	**1015**	**1059**	50732			
13	**Unit Time (days)**	**3.5**	**3.7**	175			
14							
15							
16							
17	**Constraints**			**Used**	**Available**		
18	**Eng**	1	1	50	50		
19							
20							
21	Min Time						
22		CVS	ABQ				
23	**Number to Ship**	50	0	**Totals**			
24	**Unit Cost**	**1015**	**1059**	50732			
25	**Unit Time (days)**	**3.5**	**3.7**	175			
26							
27							
28							
29	**Constraints**			**Used**	**Available**		
30	**Eng**	1	1	50	50		
31							

Figure 10: Linear Programming results for Engines Between the Bases

Based on these results, it is recommended that the engine CIRF be located at Hurlburt Field, FL.

The results for the 150 pound avionics components showed that it was faster and cheaper to ship the items from the ports to Kirtland AFB, NM. It was cheaper to ship the components to Kirtland AFB from Hurlburt Field, but it took slightly longer to ship the components to/from Hurlburt to Kirtland than to Cannon (3.5 days vs. 3.7 days). The average cost to ship the items from the ports to Kirtland was $222 and the average cost to ship the components to/from Hurlburt was $526. The average times were 3.5 days from the ports and 3.7 days to/from Hurlburt Field. Although this time of 3.7 days was slightly longer than the 3.5 days it would take to ship the item to Cannon, it is recommended based on three of the four criteria favoring Kirtland AFB that the 150 pound avionics CIRF be located at Kirtland AFB, NM.

G9

	A	B	C	D	E	F	G	H
1	Let X1 = Hurlburt Field			ST:				
2	Let X2 = Cannon AFB			X1 + X2 + X3 = 50				
3	Let X3 = Kirtland AFB							
4	MIN 246X1 + 241X2 +222X3 (Cost)							
5	MIN 4X1 + 4X2 + 3.5X3 (Time)							
6								
7								
8								
9	Min Cost							
10		HRT	CVS	ABQ				
11	**Number to Ship**	0	0	50	**Totals**			
12	**Unit Cost**	**246**	**241**	**222**	**11081**			
13	**Unit Time (days)**	**4.0**	**4.0**	**3.5**	**175**			
14								
15								
16								
17	**Constraints**				**Used**	**Available**		
18	**150lb Pkg**	**1**	**1**	**1**	50	**50**		
19								
20								
21	Min Time							
22		HRT	CVS	ABQ				
23	**Number to Ship**	0	0	50	**Totals**			
24	**Unit Cost**	**246**	**241**	**222**	**11081**			
25	**Unit Time (days)**	**4.0**	**4.0**	**3.5**	**175**			
26								
27								
28								
29	**Constraints**				**Used**	**Available**		
30	**150lb Pkg**	**1**	**1**	**1**	50	**50**		
31								

Eng | **150** | 50 | Eng HRT 2 CVS+ABQ | 150 HRT 2 CVS+ABQ | 50 HRT 2 CVS+ABQ | Matrix

Figure 11: Linear Programming results for 150 pound Avionics from the Ports

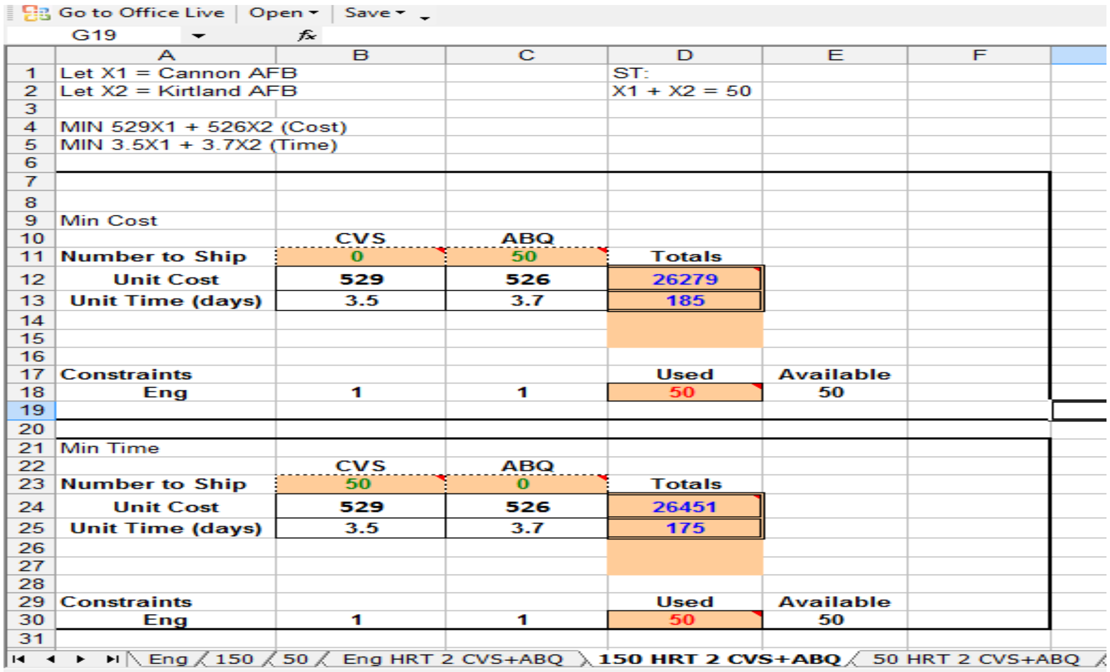


Figure 12: Linear Programming results for 150 pound Avionics Between the Bases

The results of the 50 pound avionics components showed again that it was faster and cheaper to ship the components from the ports to Kirtland AFB, and that it was cheaper to ship the components to/from Hurlburt Field to Kirtland AFB. However, once again, it was slightly longer to ship the items to/from Hurlburt and Kirtland AFB than to Cannon AFB (3.5 days vs. 3.7 days). Based on three of the four data points favoring Kirtland AFB over Cannon, and the small difference in time (.2 days), it is recommend to CIRF the 50 pound avionics components at Kirtland AFB, NM.

	A	B	C	D	E	F	G
1	Let X1 = Hurlburt Field			ST:			
2	Let X2 = Cannon AFB			X1 + X2 + X3 = 50			
3	Let X3 = Kirtland AFB						
4	MIN 246X1 + 241X2 +222X3 (Cost)						
5	MIN 4X1 + 4X2 + 3.5X3 (Time)						
6							
7							
8							
9	Min Cost						
10		HRT	CVS	ABQ			
11	Number to Ship	0	0	50	Totals		
12	Unit Cost	229	234	215	10731		
13	Unit Time (days)	4.0	4.5	3.5	175		
14							
15							
16							
17	Constraints				Used	Available	
18	50lb Pkg	1	1	1	50	50	
19							
20							
21	Min Time						
22		HRT	CVS	ABQ			
23	Number to Ship	0	0	50	Totals		
24	Unit Cost	229	234	215	10731		
25	Unit Time (days)	4.0	4.5	3.5	175		
26							
27							
28							
29	Constraints				Used	Available	
30	50lb Pkg	1	1	1	50	50	
31							

Eng / 150 / 50 / Eng HRT 2 CVS+ABQ / 150 HRT 2 CVS+ABQ / 50 HRT 2 CVS+ABQ / Matrix

Figure 13: Linear Programming results for 50 pound Avionics from the Ports

F9

	A	B	C	D	E	F
1	Let X1 = Cannon AFB			ST:		
2	Let X2 = Kirtland AFB			X1 + X2 = 50		
3						
4	MIN 521X1 + 518X2 (Cost)					
5	MIN 3.5X1 + 3.7X2 (Time)					
6						
7						
8						
9	Min Cost					
10		CVS	ABQ			
11	Number to Ship	0	50	Totals		
12	Unit Cost	521	518	25904		
13	Unit Time (days)	3.5	3.7	185		
14						
15						
16						
17	Constraints			Used	Available	
18	Eng	1	1	50	50	
19						
20						
21	Min Time					
22		CVS	ABQ			
23	Number to Ship	50	0	Totals		
24	Unit Cost	521	518	26027		
25	Unit Time (days)	3.5	3.7	175		
26						
27						
28						
29	Constraints			Used	Available	
30	Eng	1	1	50	50	
31						

Eng / 150 / 50 / Eng HRT 2 CVS+ABQ / 150 HRT 2 CVS+ABQ / 50 HRT 2 CVS+ABQ

Figure 14: Linear Programming results for 50 pound Avionics Between the Bases

It should be noted, however, that in almost all the models, the times and costs were not that drastically different. For example, the cost to ship the 50 pound avionics

components to/from Hurlburt to Cannon was only $3 more than to ship it to Kirtland AFB. Management decisions based on infrastructure at each base and mission requirements could favor another base other than the one recommended without a large impact in cost and/or time.

4.3 Excel Models for Optimal Safety Stock and Reorder Points for Each Part

As stated earlier, there were 29 parts identified as candidates for CIRF repair. These items are:

Engines		Mission Computer
Multi-Mission Tactical Terminal		Intercom Control Unit
Direct Infrared Counter Measure System (DIRCM)		Radios
Suite of Integrated Radio Frequency Countermeasures (SIRFC)		Global Positioning System (GPS)
Radar		Radar Altimeter (RALT)
Forward Looking Infrared System (FLIR)		Lighting Control Panel
Tactical Electronic Warfare System (TEWS)		Nose Wheel Assembly
Full Authority Digital Engine Control (FADEC)		Main Wheel Assembly
Blade Fold System		Landing Gear Control Panel
Drive System Interface Unit		Main Landing Gear
Gearbox		Nose Landing Gear
Proprotor Control System		Anti-Ice System
Electronics Display Unit (EDU)		Flight Control Computer
Interface Unit		Environmental Control System (ECS)
Digital Interface Receptacle Unit		

The Excel model was run on each of the parts. Each part was evaluated on its historical demand rate and individual OST. The chart below is the aircraft engine Excel model.

Go to Office Live | Open ▾ | Save ▾

O20 ▾ *fx*

PART: **ENGINES**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
	2		2	4		2		1		1	2		2	1	6	1	1	2

Lead time (months):	0.183333	AVG DEMAND/MONTH	1.3889
Service level:	0.95		

		Formulas	Comments
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.5050	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4282	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.0600	D10*D11*D12	Combining factors
Reorder point:	3.0600	D9+D13	Lead time demand + safety stock

PREP TIME	2	BASE STK	**4**
RANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TAL O&ST	5.5		

Figure 15: Excel Model for Safety Stock and Reorder Point for Engines

The historical demand was derived from the data HQ AFSOC Analysts provided. It covered an 18 month period from February 2007 to July 2008. The numbers underneath each month are the demand for that month. For example, it can be seen that two engines were demanded in May 2007 and six were demanded in May 2008. The forecasted need was based on an average monthly demand over the 18 month period. For example, 25 engines were demanded over the 18 month period. This comes out to 25 divided by 18 which equals 1.3889. All fractions were rounded up to the next highest integer, thus the forecasted demand was two. The service level was set at .95 for all the different items. Based on the service level and the forecasted demand, the model computed the safety stock and reorder point levels. The base stock level recommendation was that number rounded up to the next integer. In this case, 3.06 engines were the reorder point. Since you cannot order .06 engines, this was rounded up to four. The cargo preparation time (packing, wrapping, moving the item to the transportation dock,

etc.) and transportation time were summed to provide the total OST. The preparation time was derived from data provided by the 27th Special Operations Logistics Readiness Squadron. In the case of engines, it was two days. For the avionics components, it was one and a half days. The OST was then used to compute the lead time demand, which was used to compute the safety stock and reorder point levels.

The base stock level recommendations are as follows:

Item	Base Stock Level
Engines	4
Multi-Mission Tactical Terminals	2
Direct Infrared Counter Measure System (DIRCM)	5
Suite of Integrated Radio Frequency Countermeasures (SIRFC)	3
Radar	4
Forward Looking Infrared System (FLIR)	4
Tactical Electronic Warfare System (TEWS)	1
Full Authority Digital Engine Control (FADEC)	2
Blade Fold System	3
Drive System Interface Unit	2
Gearbox	3
Proprotor Control System	2
Electronics Display Unit (EDU)	3
Interface Unit	3
Digital Interface Receptacle Unit	2
Mission Computer	2
Intercom Control Unit	3
Radios	2
Global Positioning System (GPS)	3
Radar Altimeter (RALT)	2
Lighting Control Panel	3
Nose Wheel Assembly	5
Main Wheel Assembly	2
Landing Gear Control Panel	3
Main Landing Gear	3
Nose Landing Gear	4
Anti-Ice System	4
Flight Control Computer	3
Environmental Control System (ECS)	2

V. Conclusion and Recommendations

5.1 Introduction

This section provides concluding remarks for this research project and recommendations for future research.

5.2 Conclusion

No doubt, CIRF repair operations are becoming more and more important to the US Air Force logistics enterprise. The military can no longer afford to enjoy having full repair capabilities at every base. Manning authorizations are shrinking as are budget levels while at the same time deployments and other taskings are increasingly taking a toll on the manpower that is available.

Previous research and actual CIRF operations already in place show that CIRFs can be efficient and effective alternatives to base level repair capabilities. It is already common in the Combat Air Forces (CAF) and AFSOC to CIRF engines and avionics. This research project took that data and applied it to CV-22 specific activities. Based on the results of this study, AFSOC leadership can now make an informed decision about what to repair at CIRFs and where to locate their CIRFs. More importantly, AFSOC leadership can take the tools used for this study and manipulate them to changing situations. If additional components are added to the CV-22 (pods, for example), these can easily be analyzed using the tools provided in this study. Also, as the CV-22 matures as a weapons system and components break at different rates than they do now, that data can also be inputted into these tools to compute new requirements.

5.3 Recommendations for Future Research

As alluded to in the conclusion, changing situations with the CV-22 can easily be analyzed using the tools presented in this research project. Additionally, as new technologies come to fruition, other components that are not currently feasible to be CIRF repaired may become candidates for CIRF repair. Additional studies should be undertaken to analyze other aircraft in the military arsenal to identify new and creative ways to become more lean in their operations. The F-22 and the F-35 are just two weapon systems that are new to the US Air Force arsenal that could be studied to determine optimal CIRF locations and candidate parts for CIRF repair. For example, the F-22 is or will be based at six locations: Tyndall AFB, FL, Langley AFB, VA, Edwards AFB, CA, Holloman AFB, NM, Elmendorf AFB, AK, and Hickam AFB, HI. There is a great opportunity to identify F-22 specific components for CIRF repair and determine the optimal location(s) to repair those items.

APPENDIX A: Excel Models for Each Component

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D6 f_x =SUM(C19:C20)/30

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1		PART:	**ENGINES**																	
2	Demand History																		Forecasted Needs	
3	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	
4		2		2	4		2		1		1	2		2	1	6	1	1	2	

	B	C	D	E	F	G	H
6	Lead time (months):		0.183333		AVG DEMAND/MONTH		1.3889
7	Service level:		0.95				
8				Formulas		Comments	
9	Lead time demand:		2	SUM(T4:V4)		Summing the forecasts	
10	Standard Deviation:		1.5050	STDEV(B4:S4)		Deviation in the past demand	
11	Service factor:		1.6449	NORMSINV(D7)		Inverse of the normal distribution	
12	Lead time factor:		0.4282	SQRT(D6)		Square root of lead-time to forecast ratio	
13	Safety stock:		1.0600	D10*D11*D12		Combining factors	
14	**Reorder point:**		3.0600	D9+D13		Lead time demand + safety stock	
19	PREP TIME	2		BASE STK	**4**		
20	TRANS TIME	3.5		BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER			
21	TOTAL O&ST	5.5					

Table 1: Excel Model for Safety Stock and Reorder Point for Engines

F28 f_x

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1		PART:	**MULTI MSN ADV TACT TERMINAL**																	
2	Demand History																		Forecasted Needs	
3	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	
4	0	0	0	0	1	0	0	0	1	0	2	0	0	1	2	0	0	1	1	

	B	C	D	E	F	G	H
6	Lead time (months):		0.166667		AVG DEMAND/MONTH		0.4444
7	Service level:		0.95				
8				Formulas		Comments	
9	Lead time demand:		1	SUM(T4:V4)		Summing the forecasts	
10	Standard Deviation:		0.7048	STDEV(B4:S4)		Deviation in the past demand	
11	Service factor:		1.6449	NORMSINV(D7)		Inverse of the normal distribution	
12	Lead time factor:		0.4082	SQRT(D6)		Square root of lead-time to forecast ratio	
13	Safety stock:		0.4733	D10*D11*D12		Combining factors	
14	**Reorder point:**		1.4733	D9+D13		Lead time demand + safety stock	
18	PREP TIME	1.5		BASE STK	**2**		
19	TRANS TIME	3.5		BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER			
20	TOTAL O&ST	5					

Table 2: Excel Model for Safety Stock and Reorder Point for Multi-Mission Advanced Tactical Terminal

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F29 ▾ fx

PART: **DIRCM SYS**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	3	0	0	0	3	0	9	7	1	3	2	3	0	0	5	5	3

Lead time (months):	0.166667	AVG DEMAND/MONTH	2.2778
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	3	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	2.7398	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.8398	D10*D11*D12	Combining factors
Reorder point:	4.8398	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	**5**
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 3: Excel Model for Safety Stock and Reorder Point for DIRCM System

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F29 ▾ fx

PART: **SIRFIC**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	1	0	0	2	0	2	0	3	0	2	2	2	2	3	4	0	0	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.2778
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.3198	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.8862	D10*D11*D12	Combining factors
Reorder point:	2.8862	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	**3**
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 4: Excel Model for Safety Stock and Reorder Point for SIRFIC

PART: **MULTI MODE RADAR**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	1	3	2	0	0	2	0	0	4	1	1	1	2	3	6	2	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.5556
Service level:	0.95		

		Formulas	Comments
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.6529	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.1099	D10*D11*D12	Combining factors
Reorder point:	3.1099	D9+D13	Lead time demand + safety stock

PREP TIME	1.5
TRANS TIME	3.5
TOTAL O&ST	5

BASE STK **4**

BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

Table 5: Excel Model for Safety Stock and Reorder Point for Multi-Mode Radar

PART: **FLIR**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	2	0	6	0	1	0	1	4	5	0	0	0	1	2	1	1	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.3333
Service level:	0.95		

		Formulas	Comments
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.8471	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.2403	D10*D11*D12	Combining factors
Reorder point:	3.2403	D9+D13	Lead time demand + safety stock

PREP TIME	1.5
TRANS TIME	3.5
TOTAL O&ST	5

BASE STK **4**

BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

Table 6: Excel Model for Safety Stock and Reorder Point for FLIR

PART: **TACTICAL EW SYSTEM**

	Demand History																	Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
2					2													1

Lead time (months):	0.166667	AVG DEMAND/MONTH	0.2222
Service level:	0.95		

		Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	0.0000	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.0000	D10*D11*D12	Combining factors
Reorder point:	1.0000	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	1
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 7: Excel Model for Safety Stock and Reorder Point for TEWS

E19 BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **FADEC**

	Demand History																	Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
3	0	0	0	4	0	2	2	0	0	1	0	0	0	1	0	0	1	1

Lead time (months):	0.166667	AVG DEMAND/MONTH	0.7778
Service level:	0.95		

		Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.2154	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.8161	D10*D11*D12	Combining factors
Reorder point:	1.8161	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	2
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 8: Excel Model for Safety Stock and Reorder Point for FADEC

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **BLADE FOLD SYS**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	1	0	3	1	0	0	0	1	1	1	4	2	0	2	0	2	2	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.1111
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.1827	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.7942	D10*D11*D12	Combining factors
Reorder point:	2.7942	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	3
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 9: Excel Model for Safety Stock and Reorder Point for Blade Fold System

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **DRIVE SYS INTERFACE UNIT**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1

Lead time (months):	0.166667	AVG DEMAND/MONTH	0.2222
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	0.4278	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.2873	D10*D11*D12	Combining factors
Reorder point:	1.2873	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	2
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 10: Excel Model for Safety Stock and Reorder Point for Drive System Interface Unit

E19 — BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **PROPROTOR GEARBOX**

	Demand History																		Forecasted Needs
	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
	0	2	0	0	0	0	0	0	0	0	0	1	2	0	0	4	1	5	1

Lead time (months):	0.166667	AVG DEMAND/MONTH	0.8333
Service level:	0.95		

		Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.5049	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.0105	D10*D11*D12	Combining factors
Reorder point:	2.0105	D9+D13	Lead time demand + safety stock

PREP TIME	1.5
TRANS TIME	3.5
TOTAL O&ST	5

BASE STK: **3**

BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

Table 11: Excel Model for Safety Stock and Reorder Point for Proprotor Gearbox

J30

PART: **PROPROTOR CONTROL SYS**

	Demand History																		Forecasted Needs
	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
															2		4		1

Lead time (months):	0.166667	AVG DEMAND/MONTH	0.3333
Service level:	0.95		

		Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.4142	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.9497	D10*D11*D12	Combining factors
Reorder point:	1.9497	D9+D13	Lead time demand + safety stock

PREP TIME	1.5
TRANS TIME	3.5
TOTAL O&ST	5

BASE STK: **2**

BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

Table 12: Excel Model for Safety Stock and Reorder Point for Proprotor Control System

PART: ELECTRONIC DISPLAY UNIT

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	0	0	0	1	3	1	2	2	2	3	5	1	2	1	2	1	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.4444
Service level:	0.95		

		Formulas	Comments
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.3382	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.8986	D10*D11*D12	Combining factors
Reorder point:	2.8986	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	3
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 13: Excel Model for Safety Stock and Reorder Point for EDU

PART: INTERFACE UNIT

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	1	1	3	2	1	0	0	3	2	1	2	1	1	1	2	2	2	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.3889
Service level:	0.95		

		Formulas	Comments
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	0.9164	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.6154	D10*D11*D12	Combining factors
Reorder point:	2.6154	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	3
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 14: Excel Model for Safety Stock and Reorder Point for Interface Unit

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J29 fx

PART: **DIG INTERFACE RECEPT UNIT**

Demand History																			Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
								2	1	2	2	1				3		1

		Formulas	Comments
Lead time (months):	0.166667		
Service level:	0.95		
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	0.7528	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.5055	D10*D11*D12	Combining factors
Reorder point:	1.5055	D9+D13	Lead time demand + safety stock

AVG DEMAND/MONTH 0.6111

PREP TIME	1.5
TRANS TIME	3.5
TOTAL O&ST	5

BASE STK **2**

BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

Table 15: Excel Model for Safety Stock and Reorder Point for Digital Interface Receptacle Unit

E19 fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **MSN COMPUTER**

Demand History																			Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	0	2	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1

		Formulas	Comments
Lead time (months):	0.166667		
Service level:	0.95		
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	0.5745	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.3858	D10*D11*D12	Combining factors
Reorder point:	1.3858	D9+D13	Lead time demand + safety stock

AVG DEMAND/MONTH 0.2778

PREP TIME	1.5
TRANS TIME	3.5
TOTAL O&ST	5

BASE STK **2**

BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

Table 16: Excel Model for Safety Stock and Reorder Point for Mission Computer

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **INTERCOM CNTRLR**

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
2	Demand History																		Forecasted Needs
3	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
4	0	0	0	2	0	4	1	4	0	0	2	1	2	3	3	0	2	0	2

	B	C	D	E	F	G	H
6	Lead time (months):		0.166667			AVG DEMAND/MONTH	1.3333
7	Service level:		0.95				
8				Formulas		Comments	
9	Lead time demand:		2	SUM(T4:V4)		Summing the forecasts	
10	Standard Deviation:		1.4552	STDEV(B4:S4)		Deviation in the past demand	
11	Service factor:		1.6449	NORMSINV(D7)		Inverse of the normal distribution	
12	Lead time factor:		0.4082	SQRT(D6)		Square root of lead-time to forecast ratio	
13	Safety stock:		0.9772	D10*D11*D12		Combining factors	
14	Reorder point:		2.9772	D9+D13		Lead time demand + safety stock	
18	PREP TIME	1.5		BASE STK	3		
19	TRANS TIME	3.5		BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER			
20	TOTAL O&ST	5					

Table 17: Excel Model for Safety Stock and Reorder Point for Intercom Controller

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **UHF/VHF RADIO**

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
2	Demand History																		Forecasted Needs
3	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
4	0	1	0	1	0	0	0	2	2	0	1	0	1	2	0	0	1	1	1

	B	C	D	E	F	G	H
6	Lead time (months):		0.166667			AVG DEMAND/MONTH	0.6667
7	Service level:		0.95				
8				Formulas		Comments	
9	Lead time demand:		1	SUM(T4:V4)		Summing the forecasts	
10	Standard Deviation:		0.7670	STDEV(B4:S4)		Deviation in the past demand	
11	Service factor:		1.6449	NORMSINV(D7)		Inverse of the normal distribution	
12	Lead time factor:		0.4082	SQRT(D6)		Square root of lead-time to forecast ratio	
13	Safety stock:		0.5150	D10*D11*D12		Combining factors	
14	Reorder point:		1.5150	D9+D13		Lead time demand + safety stock	
18	PREP TIME	1.5		BASE STK	2		
19	TRANS TIME	3.5		BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER			
20	TOTAL O&ST	5					

Table 18: Excel Model for Safety Stock and Reorder Point for Radios

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **GPS**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	0	0	1	0	5	0	3	1	2	0	0	0	1	0	1	4	1

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.0000
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.5339	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.0300	D10*D11*D12	Combining factors
Reorder point:	2.0300	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	3
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 19: Excel Model for Safety Stock and Reorder Point for GPS

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **RDR ALTIMETER RCVR/XMTR**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	0	1	1	0	1	0	2	0	0	2	0	0	3	3	0	0	1

Lead time (months):	0.166667	AVG DEMAND/MONTH	0.7222
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.0741	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.7212	D10*D11*D12	Combining factors
Reorder point:	1.7212	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	2
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 20: Excel Model for Safety Stock and Reorder Point for RALT

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E19 | fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **LIGHTING CNTRL PANEL**

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
2	Demand History																		Forecasted Needs
3	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
4	0	1	3	2	4	3	3	3	1	3	1	1	1	1	2	3	2	0	2

	B–C	D	E–F	G–H
6	Lead time (months):	0.166667	AVG DEMAND/MONTH	1.8889
7	Service level:	0.95		
8			**Formulas**	**Comments**
9	Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
10	Standard Deviation:	1.1827	STDEV(B4:S4)	Deviation in the past demand
11	Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
12	Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
13	Safety stock:	0.7942	D10*D11*D12	Combining factors
14	**Reorder point:**	2.7942	D9+D13	Lead time demand + safety stock

	B	C	E	F
18	PREP TIME	1.5	BASE STK	**3**
19	TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
20	TOTAL O&ST	5		

Table 21: Excel Model for Safety Stock and Reorder Point for Lighting Control Panel

E19 | fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **NOSE WHEEL ASSY**

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
2	Demand History																		Forecasted Needs
3	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
4	0	2	6	1	0	3	1	4	3	0	0	2	5	2	6	1	0	1	3

	B–C	D	E–F	G–H
6	Lead time (months):	0.166667	AVG DEMAND/MONTH	2.0556
7	Service level:	0.95		
8			**Formulas**	**Comments**
9	Lead time demand:	3	SUM(T4:V4)	Summing the forecasts
10	Standard Deviation:	2.0428	STDEV(B4:S4)	Deviation in the past demand
11	Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
12	Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
13	Safety stock:	1.3718	D10*D11*D12	Combining factors
14	**Reorder point:**	4.3718	D9+D13	Lead time demand + safety stock

	B	C	E	F
18	PREP TIME	1.5	BASE STK	**5**
19	TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
20	TOTAL O&ST	5		

Table 22: Excel Model for Safety Stock and Reorder Point for Nose Wheel Assembly

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **MAIN WHEEL ASSY**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	1	0	0	1	1	0	1	2	1	0	0	0	1	0	0	3	1	1

Lead time (months):	0.166667	AVG DEMAND/MONTH	0.6667
Service level:	0.95		

		Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	0.8402	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.5642	D10*D11*D12	Combining factors
Reorder point:	1.5642	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	**2**
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 23: Excel Model for Safety Stock and Reorder Point for Main Wheel Assembly

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E19 ▾ fx BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **LNDG GEAR CNTRL PNL**

Demand History																		Forecasted N
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
					1	1	4					5						1

Lead time (months):	0.1666667	AVG DEMAND/MONTH	0.6111
Service level:	0.95		

		Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	2.0616	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.3844	D10*D11*D12	Combining factors
Reorder point:	2.3844	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	**3**
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 24: Excel Model for Safety Stock and Reorder Point for Landing Gear Control Panel

PART: **MLG**

	Demand History																		Forecasted Needs
	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
	0	0	0	5	0	0	1	0	4	2	0	3	0	0	1	1	1	0	1

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.0000
Service level:	0.95		

		Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.5339	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.0300	D10*D11*D12	Combining factors
Reorder point:	2.0300	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	3
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 25: Excel Model for Safety Stock and Reorder Point for Main Landing Gear

E19 f_x BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **NLG**

	Demand History																		Forecasted Needs
	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
	0	3	0	0	0	1	4	1	0	1	0	3	5	2	1	3	0	1	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.3889
Service level:	0.95		

		Formulas	Comments
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.5770	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.0590	D10*D11*D12	Combining factors
Reorder point:	3.0590	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	4
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 26: Excel Model for Safety Stock and Reorder Point for Nose Landing Gear

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E19 ▾ f_x BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **ANTI ICE CONTROL UNIT**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	0	1	1	1	0	0	3	2	0	3	11	4	3	2	0	2	1	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.8889
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	2.6097	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	1.7524	D10*D11*D12	Combining factors
Reorder point:	3.7524	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	4
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 27: Excel Model for Safety Stock and Reorder Point Anti-Ice Control Unit

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E19 ▾ f_x BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **FLT CONTROL COMP**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
4	2	2	0	0	1	0	0	2	2	0	1	2	2	0	4	0	2	2

Lead time (months):	0.166667	AVG DEMAND/MONTH	1.3333
Service level:	0.95		
		Formulas	**Comments**
Lead time demand:	2	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.3284	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.8920	D10*D11*D12	Combining factors
Reorder point:	2.8920	D9+D13	Lead time demand + safety stock

PREP TIME	1.5	BASE STK	3
TRANS TIME	3.5	BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER	
TOTAL O&ST	5		

Table 28: Excel Model for Safety Stock and Reorder Point for Flight Control Computer

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E19 ▾ *fx* BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

PART: **ECS CONTROLLER**

Demand History																		Forecasted Needs
Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08
0	3	0	0	1	0	0	0	0	0	3	0	2	3	1	0	2	0	1

Lead time (months):	0.166667
Service level:	0.95

AVG DEMAND/MONTH 0.8333

	Value	Formulas	Comments
Lead time demand:	1	SUM(T4:V4)	Summing the forecasts
Standard Deviation:	1.2005	STDEV(B4:S4)	Deviation in the past demand
Service factor:	1.6449	NORMSINV(D7)	Inverse of the normal distribution
Lead time factor:	0.4082	SQRT(D6)	Square root of lead-time to forecast ratio
Safety stock:	0.8061	D10*D11*D12	Combining factors
Reorder point:	1.8061	D9+D13	Lead time demand + safety stock

PREP TIME	1.5
TRANS TIME	3.5
TOTAL O&ST	5

BASE STK **2**

BASE STOCK = REORDER POINT ROUNDED UP TO NEXT HIGHEST INTEGER

Table 29: Excel Model for Safety Stock and Reorder Point for Environmental Control System Controller

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CIRF's up! The old new way of doing aircraft maintenance

No, I didn't misspell "surf", and I'm not talking about taking leave in Hawaii. CIRF, pronounced "surf", is an acronym for Centralized Intermediate Repair Facility. Basically, this is a repair facility that repairs aircraft parts that normally would have been done at the base level at a repair shop. Now, most of you have probably seen the hit movie "Transformers" which exhibited a lot of US Air Force aircraft, including the new CV-22 Osprey. That was the aircraft shown at the very beginning of the movie bringing the special operations team back to base. It's a pretty cool aircraft that can fly like an airplane but land and take off like a helicopter. Anyway, being a career aircraft maintenance officer, one of my first thoughts was "where and how do they fix it?" Well, I got that chance when the Air Force Special Operations Command (AFSOC) A-4M asked me to investigate that very issue.

The AFSOC A-4M didn't want to know *if* they should CIRF the CV-22. That was a given. CIRF operations have actually been around quite awhile, even though it seems to be a new concept to most of us in the Air Force today. It has been experimented with by the Air Force ever since it became an independent service. Thus, it's the old, new way of aircraft maintenance. Like it or not, they are here to stay, and here are the reasons.

1. They save a lot of money! AFSOC has already started CIRF operations on its C-130 fleet. The manpower and cost savings can be huge. Just think about it. If you take all the folks who would have been doing that work at each base and centralize

them in one place, obviously you wouldn't need *all* those folks. Additionally, CIRF operations take advantage of contract and civilian technician expertise since the CIRF does not forward deploy. Thus, savings in salaries and benefits, plus cost value of time by using expertise to help expedite the maintenance processes are realized.

2. They ensure all bases that have that aircraft get a fair share. Face it, we just don't have the money and manpower anymore to make sure every base has its warehouses full of spare parts. Our leadership from the Chief of Staff on down has said that if the standard for in-commission aircraft is 80 percent, then your goal should be 80 percent. That's a huge mind-set change. Now, if one base has a 90 percent in-commission rate and another base has a 70 percent in-commission rate, who do you think is going to get the help? The 70 percent base.

3. Finally, they work! Remember, CIRFs don't forward deploy, by definition. That means you can employ civilian and contract technicians who have tons of experience. I don't know of any maintainer who wouldn't dream about have a shop full of highly experienced and qualified non-commissioned and senior non-commissioned officers! This is not to say there wouldn't be any blue-suiters. Quite the contrary. The experience our younger airmen can gain from working with these highly experienced civilian personnel is invaluable.

As much as a lot of bases would hate to lose their in-house maintenance capabilities, the new realities are that we just don't have the money or the people to do so. CIRFs will enhance our combat capability while achieving cost and personnel savings. It's just good business.

Major Rowe is a career aircraft maintenance officer and student at the Air Force Institute of Technology working towards a Masters of Logistics Science.

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14. ABSTRACT

The CV-22 Osprey is a revolutionary weapon system that is currently being fielded by Air Force Special Operations Command (AFSOC). It is a tilt-rotor aircraft that combines the speed of a conventional fixed wing turboprop aircraft with the flexibility of a helicopter. At the same time, the US Air Force logistics enterprise is turning more and more to centralized aircraft maintenance. The term for these centralized maintenance facilities is centralized intermediate repair facilities, or CIRF. The Headquarters AFSOC logistics directorate (A-4) is interested in determining where CIRF(s) for the CV-22 should be located and what parts should be repaired at a CIRF versus at the base where the aircraft is stationed. This research study analyzed cost and transportation time data to identify recommended CIRF locations. It also analyzed historical failure and demand data for particular CV-22 parts to determine which parts are candidates for CIRF repair and what stock levels should be established at the bases so that parts are available to repair the aircraft while the CIRF repairs failed parts.

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